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ABSTRACT

The project reviewed literature, surveyed manufacturers, and interviewed handicapped and elderly consumers of information-age technologies in an attempt to identify important accessibility issues with respect to emerging information technologies, particularly the personal computer. Results suggested that personal computers appear to be moving toward less rather than greater accessiblity for persons with hearing, vision, mobility and learning limitations, and that the two most critical considerations are redundancy and transparency. Redundancy, the provision of information both visually and auditorially, will prove to be a major benefit to deaf and hearing-impaired, blind and visually impaired, learning-disabled and retarded individuals. blind and visually impaired, learning-disabled and retarded individuals. Transparency refers to steps which make it impossible for the machine to "know" whether information is entered directly on its keyboard or through some other input mechanism; transparent technologies may be used by persons having difficulty manipulating keyboards, including many persons with arthritis and other physical limitations. Further work is necessary before formal standards for accessibility to information-age technologies may be formulated. A national conference of hardware and software manufacturers, disabled and elderly consumers and experts on accessibility was proposed. (Author/CL)

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ACCESS TO INFORMATION-AGE TECHNOLOGIES

Report on an Exploratory Project Examining the Issue of 'Accessibility' for Handicapped and Older Persons to Emerging Information Technologies

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EXECUTIVE SUMMARY: ACCESS TO INFORMATION-AGE TECHNOLOGIES

With support from a grant from AT&T, the University of Arkansas Rehabilitation Research and Training Center reviewed literature, surveyed manufacturers and interviewed handicapped and elderly consumers of information-age technologies in a project designed to identify important "accessibility" issues with respect to emerging information technologies.

This exploratory project concentrated upon personal computers as proxies for information technologies because manufacturers and literature revealed that microcomputers increasingly are being used in business and in the home to access what is often called "the information age."

Interviews with consumers, surveys of hardware and software manufacturers and reviews of relevant literature highlighted some major accessibility problems. Personal computers appear to be moving toward less rather than more accessibility for persons with hearing, vision, mobility and learning limitations. This is a matter of some concern given that several tens of millions of Americans are restricted in one or more of these ways. Unless some steps are taken to make information technologies more accessible, they may be shortchanged.

Probably the two most critical considerations are redundancy and transparency. Providing information both visually and auditorially will prove to be of major benefit to deaf and hearing-impaired, blind and visually impaired, learning-disabled and retarded individuals. By contrast, offering information in one modality but not in another, or some information in one and some in another, poses serious accessibility problems for these persons. Transparency refers to steps which make it impossible for the machine to "know" whether information is entered directly on its keyboard or through some other input mechanism; transparent technologies may be used by persons having difficulty manipulating keyboards, including many persons with arthritis and other physical limitations.

Further work is necessary before formal standards for accessibility to information-age technologies may be formulated. To stimulate such efforts, the project staff proposed a national conference between hardware and software manufacturers, disabled and elderly consumers and experts on accessibility. That meeting tentatively is planned for the White House in February 1984.

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ACCESS TO INFORMATION-AGE TECHNOLOGIES

Introduction

In the United States today, approximately 27 million to 36 million people are disabled. They have, that is, permanent limitations of activity which affect their ability to work or do housework, benefit from education and other social services, and participate actively in community life.

As America leaves a "Postindustrial Age" and enters an "Information Age," the question must be posed: "What is being done to ensure that millions of people with 'special needs' are not being left behind?"

The question is particularly poignant in that the massive construction that characterized this country's growth for the first three-quarters of the twentieth century proceeded with little if any public attention to that question. As a result, in the late 1970's, laws were passed, regulations were promulgated, and several billions of dollars were spent to "retrofit" an inaccessible America. Are we about to repeat that pattern?

This project was conducted as one effort to prevent so serious a mistake. The work was exploratory in nature: it sought more to raise questions than to provide definitive answers. Nevertheless, some tentative directions for future action have emerged.

It is our hope that this document represents a beginning of a much-needed and long-overdue consideration of the needs of disabled and older Americans in an "Information Age".

Background

This project was funded by AT&T, in a grant to the University of Arkansas Rehabilitation Research and Training Center, Fayetteville. The ARRTC is supported by the University and by Arkansas Rehabilitation Services, the state vocational rehabilitation agency. Since 1965, it has conducted a series of research and training projects on rehabilitation of persons with disabilities, many of which were sponsored by the Federal Government.

The project was proposed during an 8 July 1983 meeting of AT&T District Manager Angela Tedesco, AT&T District Manager Jay Rochlin and ARRTC Visiting Professor Frank Bowe at AT&T's 195 Broadway headquarters building. At its 3 August 1983 meeting, AT&T's contributions committee approved a grant for the proposed work.

In September 1983, the project began with Dr. Bowe assuming responsibility as project director. The cooperation of the Arkansas Rehabilitation Services agency was secured from E. Russell Baxter, Commissioner. ARS staff identified disabled individuals in the State known to be using computer-related information technologies. These persons were contacted and asked to participate in the study, as were others in the States of New York, Maryland, and Virginia, as well as in the District of Columbia. Interviews with these persons, at the locale of the computers they used, were conducted by the project director in October and November.

Meanwhile, literature on high technology and disabled persons was collected and reviewed. In the fast-moving and still-young computer field, magazines and journals proved much more valuable than did textbooks. Byte, Personal Computing, Popular Computing, Business Week, Fortune, Forbes, High Technology, the now-defunct Technology Illustrated, U. S. News & World Report, Time, Newsweek, and Inc. magazines were reviewed in toto, covering all 1983 issues. Among the few books found to be helpful were Bazar's Ergonomics in Rehabilitation Engineering, Cakir's Visual Display Terminals and Stern and Redden's Technology for Independent Living.

In November, more than 100 hardware and software manufacturers were surveyed about the accessibility features of their products. Thirty-five replies (30%) were returned and considered complete. Responses were tabulated and analyzed, with findings integrated into this report.

The project's final activity was to arrange with representatives of the Federal Government to sponsor a national conference bringing together selected representatives from the industry, the major consumer groups and the professional fields involved in accessibility work. The White House is expected to host that meeting in February 1984. Because the conference is not a project activity under the project staff's control, its proceedings are not included in this report.

Technical Aspects

As the project began, it was becoming clear that the technology of choice for information-age tasks was the personal computer. Business Week, in a 3 October 1983 cover story discussing the IBM PC, made this point:

> "The unexpectedly rapid success of the PC also is enabling IBM to keep up with another major industry trend that neither the computer giant nor its competition had expected. Personal computers in general, and the PC in particular, are becoming the most popular method for professionals and executives alike to tap into information processing." (p. 86)

As Personal Computing magazine's phenomenal growth shows as well, home and personal computers are being used increasingly by consumers in the home to tap into "Information Age" services and products.

Because of the powerful trend toward personal computers, and because of a belief that findings we obtained with such devices likely would be generalizable to other kinds of computers and information technologies, the project concentrated upon access to personal computers.

A related technical decision further delimited the scope of the project. While tens of millions of Americans have what might be called "special needs," these needs are variations upon basic themes: those problems disabled and older persons have in receiving information and those difficulties these people encounter in manipulating information. Accordingly, the project focused upon input and output questions.

A third technical decision was made. In the belief that accessibility for persons who are severely disabled in some way also would provide, in most instances, accessibility for individuals less severely disabled in these ways, the project concentrated upon the problems of severely disabled persons.

Finally, the decision was made that the most valid and reliable source of information about these problems was the consumer. The project sought to interview, in person and at the computer location, severely disabled individuals. The information these persons provided was cross-referenced with professional literature and with manufacturers in an effort to identify the precise nature of the problems being reported by the consumers.

Limitations

This project was preliminary in a number of ways.

First, by its duration. Begun in September, it concluded in December. The short time frame was dictated by the limitations in funding: in Federal contract terms, less than one-sixth of a "person year of effort" was involved.

Second, by the technical decisions made. Some of these decisions may have restricted the scope of the generalizability of the findings. For example, it may be that steps taken to make personal computers "accessible" to persons with, say, severe hearing disabilities may not also provide accessibility to persons with mild or moderate hearing losses.

Third, by the limitations of the data collected While a thorough literature search was conducted, some important sources may have been overlooked. Similarly, the sample of slightly less than three dozen severely disabled individuals in four States and the District of Columbia may have produced some statistical artifacts that a larger sample might have obliterated. And responses from manufacturers were fewer in number than we would have liked.

For all of these reasons, the project must be viewed as a preliminary one. The planned February conference will be another important step in the effort to delineate more surely the nature of the problem and the dimensions of the feasible solutions.

Further work may become necessary. Just as standards will be needed, eventually, for technical specifications on, for example, disk size, so, too, it may become necessary, or at least helpful, for standards to be developed to guide hardware and software manufacturers in their efforts to make their products "accessible". Such standards are beyond the scope of this project.

Persons with Special Needs

With respect to information-age technologies such as personal computers, several limitations of activity are important. These are referred to, collectively, in this paper as "special needs".

Vision. About 11 million Americans of all ages have impairment of vision; more than half of these persons are over 55 years of age. About 1.7 million individuals have severe visual impairments, of whom about 450,000 are legally blind.

Blindness is defined as 20/200 vision in the better eye, with correction, or a visual field subtending at an angle of less than 20 degrees. Generally, a blind person could perceive a symbol on a Snellen chart at 20 feet that an individual with normal vision could see at ten times that distance.

Severely visually impaired or blind persons often cannot read information on a display as normally configured. Many can, however, read magnified images. Others rely upon auditory and/or tactile cues.

Hearing. Approximately 14 million Americans of all ages have losses of hearing in one or both ears; about half are over 55 years of age. Some 2 million are deaf. Deafness is the inability to understand conversational speech through the ear alone regardless of amplification.

Persons with severely impaired hearing often are unable to comprehend clearly spoken messages on the telephone or from a computer terminal; many will not hear the "beeps" some computer programs produce, regardless of amplification.

Physical Mobility. Some 10 million Americans have restrictions of mobility, usually with the upper or lower limbs. About one-half million use wheelchairs. Several million others have severe fine-motor control limitations affecting finger mobility, as with arthritis, cerebral palsy, and quadriplegia.

These persons tend to encounter two major problems with telecommunications and other information-age technologies. One is reaching: persons using wheelchairs usually can reach no more than 20" past a desk edge. Another is keyboard control: individuals with cerebral palsy and arthritis as

well as quadriplegia have difficulty positioning the fingers accurately and consistently on the close-packed keyboard.

Learning. Learning disabilities have attracted much more attention in recent years. With dyslexia, an individual has difficulty interpreting visual information such as print although the eyes themselves generally are not impaired. With some other kinds of learning disabilities, interpretation of auditory information is sharply limited, despite the fact that the auditory organ functions normally. Most learning-disabled persons have normal or near-normal general intelligence.

Retardation is a general reduction in level of functioning. Persons who are retarded often respond more satisfactorily to spoken than to printed messages, and most appropriately to demonstrated or acted-out requests or instructions. Experience in classrooms suggests that many retarded persons learn very well with the patient, uncritical intervention of a computer.

We have less satisfactory statistics on the prevalence of learning-related disabilities than we do on sensory and physical restrictions, but we do know that several millions of Americans are affected.

Speech. About two million Americans of all ages have severe speech impediments that are not correctable surgically. Often, emotional stress during the speech-development years of childhood results in stuttering and other speech restrictions; persons with such limitations usually are of normal emotional stability and intelligence as youths and as adults. But they may have difficulty pronouncing words distinctly, consistently, and discretely as required by current speech-recognition technologies.

The Promise

The emergence and rapid spread of personal and home computers sparked tremendous interest among persons with special needs throughout the nation because these devices seemed to have almost unlimited potential for serving as "accommodations" to meet their needs.

For persons who are deaf, for example, the computer seems tailor-made. Almost all commercial software now available relies upon visual display rather than artificial speech or sound to convey information; among computer games, fewer than one dozen require the player to hear. And other features of computers seem

to promise even more help. Spelling checkers are wonderful for persons who lost their hearing early in life and had great difficulty mastering the English language. On the horizon are speech-recognition capabilities that seem to promise that the computer will open the door to telephone, in-person, television, and even radio speech comprehension. Coming, too, are grammatical construction checking programs that would help persons with difficulty framing correct syntax. Such capabilities literally would change the lives, forever, of deaf and severely hearing impaired persons.

Blind individuals, too, became very excited about the advent of the affordable computer. Synthesized speech devices priced at $200-$300 enable them to listen to words and numbers others see on the screen. Other interfaces, such as a specially-equipped Optacon, can provide tactile versions of displayed information. With personal and home computers, blind individuals reasoned, they could leapfrog the old bugaboo that "you can't keep up with the paperwork".

Physically disabled individuals as well demonstrated keen interest in personal and home computers. These devices may act at a distance, such that someone with a severe mobility restriction could work from the home almost as well as from an office, eliminating the need for the exhausting and always difficult commute to work. Personal computers, too, can control electrical devices in the office and in the home such as lights, heating and air conditioning equipment, alarm signals, and the like, saving sizable amounts of energy and time.

Learning-disabled persons celebrated the capacity of the computer to process information from the modality they could not process well to one they could. Dyslexic persons, for example, could draw upon the same synthesized-speech technologies blind people found so helpful to "read" information from a screen. Persons whose learning disabilities interfered with the interpretation of auditory information could read rather than listen to information. And retarded individuals could spend as much time as needed, without risking the impatience of a teacher, to master material.

These promises loomed especially large because the effort to retrofit an inaccessible America has yet to be completed. Public transportation systems, to illustrate, remain largely inaccessible to persons using wheelchairs. Telephones may be used by deaf persons only to call others having specialized equipment, called Telecommunications Devices for the Deaf; the development of "Picturephone" was stalled in the 1970's. Kurzweil Reading Machines, which translate print to voice, remain prohibitively costly.

The Reality

The fact that personal and home computers were being designed, not to meet the special needs of disabled and older persons, but to satisfy the desires of the general population inexorably began to erode the promise that once appeared so glittering.

Blind persons, for example, quickly learned that purchase of an inexpensive speech synthesizer gained them access only to a very small fraction of available commercial software. Because most such software is "protected," it has features that interact with the disk operating system in such a manner as to prevent the user from copying the program. These same features also prevent information from being sent to the speech synthesizer. Accordingly, blind persons using Votrax, Echo or other speech synthesis technologies found that the only information they could get read aloud was that which had been processed by unprotected or specially adapted software. When a number of blind individuals protested to software manufacturers, they were rebuffed: the concerns of the producers about unauthorized copying of disks overrode the comparatively-minor issue of inaccessibility for blind persons using speech synthesizers because demographically the general market dwarfs that of blind persons.

Another problem then surfaced. The technologies introduced by Xerox with its Star workstation, particularly the use of icons or images, began to spread, first to Apple's Lisa and then to other hardware and software products. These images cannot be read by a speech synthesizer. The emergence of "windows" on the screen, sophisticated graphics, and other visual display mechanisms also proved to be unreadable by the Votrax, Echo and similar machines.

Personal and home computers will be most helpful to blind persons if these are so configured as to enable these individuals to use the same hardware and software as classmates in school and coworkers in offices are using. The emerging reality is that they will not be, at least not in the foreseeable future. Rather, blind persons will be able to use some computers (notably Apple IIe's) and some software (particularly public-domain, user-designed, or specially prepared packages). And the trend is toward more, not less, inaccessibility. General-public users appreciate the "user-friendly" icons, mouses, and other features that pose so many problems for persons using speech synthesizers.

Eventually, perhaps, commercially available software will have its own built-in synthesized speech capabilities that will obliterate the interface problems now being experienced by many blind persons. But only perhaps. There is no evidence now discernible that hardware or software manufacturers are taking the "special needs" market seriously enough to plan for such developments. Rather, such happy changes will be accidental. Or they may not occur at all.

As Gregg Vanderheiden of the University of Wisconsin at Madison's Trace R&D Center, and an acknowledged expert on personal computers and handicapped individuals, says in an as-yet unpublished paper: "As the computer is advancing handicapped individuals two steps through the use of special programs designed for handicapped individuals, the computer is advancing everyone else in society five steps."

With respect to persons who are deaf, similar problems are beginning to emerge. We are seeing in the computer games field that programmers are taking advantage of the growing power of personal computers to introduce synthesized speech and artificial sound into the games; a deaf person cannot play games which require comprehension of spoken instructions or perception of different kinds of auditory signals. The very integrated speech-synthesizer capabilities that might help blind persons use commercial software may render such programs inaccessible to deaf individuals. And although the speech-recognition realm is developing very rapidly, there is no assurance at present that computers capable of recognizing speech will be designed in such a way as to enable deaf persons to use, for example, the telephone: there may be limitations of memory, of speech-recognition vocabulary, and of interfacing equipment that would prevent such specialized uses. Again, computer hardware and software manufacturers are responding, not to the needs of deaf persons for technology to help them understand speech, but to the demands of the general public for "user-friendly" products. There remains the possibility that reaching the latter goal, which is to the manufacturers much more important than the former, would be incompatible with meeting the needs of deaf persons. If so, what may happen is that personal and home computers, today so very accessible to deaf persons, may in the future become dramatically much less so.

Learning-disabled persons may find, to their chagrin, that hardware and software products are designed to tap both hearing and vision; that is, some commands or data may be displayed visually and some auditorially, within the same program. Dyslexic persons might discover that they could hear, and process, so few of the signals that using the program was impossible.

For persons who are retarded, the drive by computer programmers to tap the ever-growing power of personal computers to develop ever-more complex programs may leave these individuals behind. This may be particularly true if programmers follow the lead of educators influenced by the "Sesame Street" approach of mixing sight, sound, and other modalities in order to tap as many input capabilities of the normal child as possible.

Physically disabled persons today often use what are called "keyboard emulators," that is, specially designed input mechanisms they can use much better than they can the standard keyboard. As is the case with speech synthesizers, "protected" software's interference with the operation of a disk operating system often prevents use of such emulators with commercial software. Another problem has to do with the power of currently available personal computers. Even 16-bit machines often cannot perform more than one task at a time. As Vanderheiden has indicated ("Computers Can Play a Dual Role for Disabled Individuals," Byte, September, 1982, 136 et seq.), many severely disabled persons need a "multi-tasking" capability: they may need, for example, to use the computer with its modem to handle telephone calls without having to download a commercial software program. It is possible, although not yet demonstrated with products on the market, that 32-bit desktop computers such as those under development by AT&T and IBM, may be capable of such sophisticated switching. Vanderheiden also speaks of "multi-level" programs, which can accept information from one level into a second level. For someone who needs to use a special subroutine to enter words or data into a computer, it is often necessary now to employ two terminals, not just one. One terminal displays the options on a menu, from which the user selects the desired data; the other terminal displays the commercial program. It is possible, but again not certain as of yet, that the more powerful 32-bit machines may meet these special needs.

The reality today is that computers are much less accessible than they might at first appear to be. And the direction of effort is toward less, not more, accessibility.

We face the prospect of leaving tens of millions of Americans out of the "Information Age" if these current and projected problems are not recognized and resolved.

If we fail to do so, it will be a tragic irony. Personal computers and other information-age technologies have the potential of helping persons with special needs participate fully in the life of our nation: quite literally, these machines can overcome the limitations of people with special needs. They can hear for deaf people, see for blind people, move information for mobility restricted individuals, and provide patience and repetition for retarded individuals.

Some Next Steps

It is still possible to arrest, and reverse, the unfortunate trend toward decreased accessibility.

The field of information-age technologies is still in its relative infancy. Standards for hardware remain elusive, although the MS-DOS and UNIX operating systems and the IBM PC architecture are becoming de facto standards in many respects. Advanced 32-bit desktop computers are expected to comprise some 80% of all desktops sold by 1990, according to Forecasting International; the fact that few such machines have yet been introduced to the mass market offers some hope that they may be made accessible at relatively little cost.

As of November 1983, industry experts state that fewer than 10% of business executives use computers or feel comfortable around them ("Why Executives Don't Compute," Fortune, November 14, 1983, pp. 241-246). Although more than half of the nation's schools have at least one computer, indications are that millions more such machines will be purchased in the years to come, according to Education Turnkey Systems. And Personal Computing estimates that fewer than 10% of the nation's families have personal or home computers.

Similar trends are evident with respect to other information-age technologies. The number of persons now using electronic means to do banking, shopping and other kinds of transactions through such services as Viewtron, a service of Knight-Ridder and AT&T, or HomeBanking, a service of Bank of America, still is figured in the thousands rather than in the millions. Sophisticated telephones such as AT&T's Genesis have just been introduced.

For all of these reasons, it is probably timely now to draw upon the experiences to date of disabled and older persons to suggest ways in which information-age technologies may be made more accessible.

Yet the realities of the marketplace must be respected.

It is unlikely that computer software manufacturers will be willing to scrap the features that protect their programs from being copied. It is also improbable that hardware manufacturers will respond to more than a very few special needs that are not congruent with the needs of the general public. And with competition so stiff, it appears unlikely that any hardware or software manufacturer will adopt changes in design that are costly or that require lengthy development. The project's survey of manufacturers made these points quite clear.

Recognizing these constraints, we offer below some suggestions drawn from personal interviews with severely disabled individuals who own or use personal computers, discussions with experts in the field of adaptive peripherals, and review of relevant literature. The proposals are presented neither in ascending nor in descending importance because what is important for one person may be irrelevant for another. All of the suggestions, however, appear both necessary for many individuals with special needs and technically feasible for manufacturers to adopt at relatively minor cost.

1. Redundancy. When information is presented in one mode (e.g., displayed on a screen), offer the same information in a second mode (e.g., auditorially). This suggestion would prevent inaccessibility in future software for deaf persons (who couldn't hear auditory-only information), blind people (who couldn't read visual-only data), and learning disabled individuals (who may be unable to process information in one of the modalities).

   The same suggestion applies to tactile input modes. If a "mouse" is used, for example, it should also be possible to input the same information on the keyboard. If a touch screen is used, as with Hewlett Packard's 150 personal computer, it should be possible to keyboard the same information.

   It probably would not be necessary to provide redundancy on a simultaneous, real-time basis. That is, it would be acceptable if information could be put into and taken out of a computer by one mode at a time, as long as another mode also were possible.

   What should be avoided, if at all possible, is software or hardware that permits only one mode of input or output for particular functions.

2. Transparency. This technical term refers to functions which make it impossible for the computer to "know" whether information is being entered from the keyboard or from some other source. Transparency is related to redundancy in that transparency facilitates the use of different input and output modes. The use of keyboard emulators, for example, would be greatly expanded in potential were computers more transparent to alternative input mechanisms.

3. On/Off Switches. On many terminals, such as Apples and CPT machines, the on/off switch is located at the very back of the machine in order to prevent accidental or unauthorized use. Such switches, however, are beyond the 20" reach of many physically disabled persons, including many using wheelchairs. It may be possible to design an on/off switch that is located at the front of the terminal but is designed in such a way as to prevent misuse; examples would include an automatic interrupt routine which would query the user: "Off? Yes/No?" or the use of a two-step off mechanism in which something else must be done before, after, or while the off switch is depressed (as "Control/Off"). Other alternatives include special coloring (red, for example) of the on/off switch. While we believe it is important to explore this issue, it may be that the consequences of accidental or unauthorized use of the on/off switch are so serious (loss of memory, for example) that this represents a case in which the special needs of older and disabled persons must take a back seat to the more general problem.

4. Detachable Keyboards. Fortunately for persons with special needs, such keyboards are popular with the general public. Persons with mobility restrictions, particularly those using wheelchairs, often prefer to place the keyboard on a wheelchair lapboard. This requires, not only detachability, but also an elongated cable or some mechanism such as the IBM PC Junior's infrared signal which enables the user to position the keyboard as far away from the central processing unit as twenty feet. If a cable is used, a four-foot length probably will suffice to meet most special needs.

5. Keyguards. Specially designed keyguards, which help persons with cerebral palsy, arthritis, and other fine-motor disabilities can cost as much as $110 if custom designed but may cost only one-tenth that much if made available by the manufacturer.

   An important keyguard feature is an automatic depressing mechanism for control and shift keys. Persons with severe fine-motor disabilities may not be able to depress two keys simultaneously; few computer keyboards feature a control-lock capability.

6. Dvorak Option. A Dvorak keyboard differs from the standard QWERTY keyboard in that the most-often used keys are located in the "home" row, making it possible to type many words without moving the position of the hands at all. Apple has announced that it will make a Dvorak keyboard available for its IIe and III computers. DEC may follow suit. For physically disabled persons as well as older individuals with arthritis, the Dvorak may be much easier to use than the awkward QWERTY keyboard. See, for example, "A Keyboard Whose Time Has Come," Inc., June, 1983, 43-45.

7. Character Display. For visually impaired persons using Optacon devices, availability of a standard character size would be most helpful because the Optacon is limited in its capacity to "read" different sizes of display images. Optacon users, too, need an "active" (CRT) display rather than a "passive" (LCD) display for the peripheral aid to work.

8. Additional Memory. Given the always-important issue of affordability, the potential of 32-bit desktop computers to meet the needs of hearing, vision, and mobility impaired persons is very great because the additional memory makes it possible to include multi-level, multi-tasking, speech-recognition and speech-synthesis capabilities in commercial programs. We hope that developers of these advanced machines will recognize the special needs of disabled and elderly persons and avoid installation of features which would defeat these desireable purposes.

9. Protection. As indicated earlier, we recognize that it is very unlikely that software manufacturers will retreat from their position on protection against copying disks. But the issue is so important that we hope they will at least explore other ways of protecting the programs, ways which will not prevent use of speech synthesizers or keyboard emulators.

10. Portability. Persons with special needs often desire to use the great capabilities of personal computers for purposes other than those served at a desk. Portability would help speech-impaired persons, for example, use a computer in conversation, a blind person to use one to take notes in class, and a physically disabled person to use a computer in more than one location. At present, it does not seem that the potential of the 32-bit machines will soon be joined by the advantages of portability, but no one who has watched the computer field for more than a few months doubts that someday 32-bit portables will be on the market.

Of all the measures we would advise manufacturers to consider, probably the most important is: "Listen to people with special needs."

A dialogue between disabled and elderly persons, on the one hand, and manufacturers on the other is almost certain to produce greater empathy on each side of the problems faced by the other---and agreement upon feasible, cost-effective steps that can be taken.

Prospects

What are the chances that hardware and software manufacturers will take into consideration the special needs of older and disabled persons when designing new products?

Recent history is not reassuring: those attempts of which we are aware almost all have been rebuffed, as disabled persons complaining to manufacturers learned to their regret that the imperatives of the marketplace overruled special considerations.

However, there are two factors which argue for brighter prospects.

One is the size of the market for special-needs computing. At least four million handicapped children are in the public schools, according to a 1983 compilation of state reports by the U. S. Education Department. More than 13 million Americans between the ages of 16 and 64 are disabled, according to the highly respected Current Population Survey of the U. S. Bureau of the Census. Another 4.7 million people aged 65-74 are disabled, according to the 1982 CPS.

Most of these people have family members who are tuned to their special needs and will consider, as one factor related to purchase of hardware and software, accessibility features important to their relatives at home. At least seven million disabled persons work for employers who may take into consideration accessibility features of business-use systems.

A second feature not yet important in the marketplace, but looming in the distance, is intervention by government. When buildings were recognized to be inaccessible, the Federal Government passed a series of laws requiring that all new construction be "barrier free" and that existing structures be retrofitted to accessibility when scheduled for renovation.

Regulations such as those for section 504 of the 1973 Rehabilitation Act also were promulgated. Most of the costs incurred in retrofit were borne, not by the Federal Government, but by the private sector.

Most observers in the disability community would prefer that voluntary, marketplace measures take precedence over forced compliance with Federal statutes. Still, the possibility that government eventually may be forced to step in to regulate specifications of equipment should not be overlooked.

Perhaps the deciding factor will be utilization of technology. Persons close to the development of information-age technologies have a natural desire to see their inventions and creations used in the broadest possible spectrum of ways and means by the largest possible body of people. We have seen, for example, that ABC-TV and PBS remain highly committed to "close-captioned" television that benefits hearing-impaired viewers despite the fact that relatively few closed-caption decoders have been sold to date.

Personal computing today is often described as "the new religion." Without being sacrilegious, we can observe that persons who have discovered the enormous potential of personal computers exhibit an enthusiasm about these products that closely approximates that of "born-again" Christians. Some experts persist in explaining that computers are just tools, like typewriters. But most of us who have used computers don't feel that way. Such commitment may augur well for the future of computing for persons with special needs because it may impel developments that will meet their needs without sacrificing market imperatives.

Information-age technologies other than personal computers, such as the Viewtron terminals for videotex, Gemini telephones and the like may share with personal computers a susceptibility to adaptations to meet special needs along the lines suggested in this report. In particular, redundancy, transparency, portability, Dvorak keyboards and the like may prove to be ways in which a multitude of information-age technologies may become more accessible to persons with special needs.

Much work remains to be done before specifications that are precise, feasible, cost-effective, and subject to mass production may be identified and proposed as possible standards. This report is only one small step on a long road. We conclude with the expression of hope that others will take up the task.

Annotated Bibliography

Bazar, A. R. Ergonomics in Rehabilitation Engineering. Wichita, KS: Rehabilitation Engineering Center, Cerebral Palsy Research Foundation of Kansas, 1978. Discusses five studies on the anthropometric dimensions of designing workplaces for disabled individuals and compares these data to comparable figures relating to nondisabled persons.

Bowe, F. Computing and Special Needs. Berkeley, CA: Sybex, 1984. This forthcoming consumer-oriented publication discusses how older and disabled persons can benefit from microcomputers.

Bowe, F. Demography and Disability. Hot Springs, AR: University of Arkansas Rehabilitation Research and Training Center, 1983. This chartbook summarizes 1981 and 1982 demographic data on the nation's population of disabled individuals of working age.

Cakir, A., et al. Visual Display Terminals. New York: John Wiley and Sons, 1980. An excellent, albeit European-oriented, overview of ergonomic considerations in design of VDTs.

McNeil, J. Labor Force Status and Other Characteristics of Persons With a Work Disability. Current Population Reports, Special Studies, Series P-23, Number 127. Washington, D.C.: U. S. Government Printing Office, 1983. An excellent technical presentation of the findings of the 1982 Current Population Survey March study of disabled persons.

Stern, V., and Redden, M. (Eds.) Technology for Independent Living. Washington, D.C.: American Association for the Advancement of Science, 1982. A fine collection of presentations on the issues of accessibility to modern technologies.

Taeuber, C. America in Transition: An Aging Society. Current Population Reports, Special Studies, Series P-23, Number 128. A very rich compilation of data on the fastest-growing segment of the American population, that of persons over 65 years of age.

Vanderheiden, G. Comparison of Apple, Epson, IBM...Microcomputers for Applications in Rehabilitation Systems for Persons with Physical Handicaps (Revision C). Madison, WI: University of Wisconsin-Madison Trace R&D Center, 1983. A fine review of accessibility issues related to personal computers. Includes the author's Byte article as an appendix ("Computers Can Play a Dual Role").

Appendix A

A total of 118 manufacturers (43 hardware, 75 software) were surveyed using the two enclosed questionnaires. Responses were received from nine hardware manufacturers (20.9%) and from 26 software manufacturers (34.7%), for a combined response rate of 30%. Key findings:

Hardware

- 56% reported that the keyboard was separable. That is something many physically disabled persons need.
- All respondents reported that shift-lock keys were standard but only 22% reported control-lock keys as standard. Some physically disabled persons have difficulty depressing two keys simultaneously.
- 78% reported that characters are illuminated by an "active" display rather than by the "passive" LCD. Blind persons can use an Optacon to read active but not passive displays.
- Only 33% reported that audible alarm signals are also given to the user visually. Deaf persons often cannot hear audible signals.
- 89% said an RS-232 interface is available. That's important to disabled and older persons who need to use peripheral equipment with a computer.
- 78% reported the computer to be portable. Many disabled persons appreciate portability so as to use the device for communication as well as for computation purposes.
- 44% believe speech synthesizers may be used with their products. Blind and learning-disabled persons need these.
- Only 11% stated that a Dvorak keyboard was available as an option. Such layouts may be easier for older and disabled persons to use.
- 67% report that displays blink at fewer than 5 Hz. Persons with epilepsy may be susceptible to seizures at higher frequencies.

Software

- o 58% said the programs were protected. Some peripherals such as speech synthesizers may not work with protected software without extensive modifications in hardware.
- o Just 27% observed that software alerts users both auditorially and visually to critical information. Deaf persons may not hear audible signals.
- o Half (50%) said analog inputs may be used (e.g., game paddles). Some special-needs peripherals are analog.
- o Multi-tasking (23.1%) and multi-level (26.9%) programming was the exception rather than the rule.
- o About one-fourth (26.9%) said they would consider speech and other alternative input capabilities in future programs while 34.6% said their current programs allow such alternative modalities of input.

Other Comments

Manufacturers were asked to provide comments in addition to responding to questions posed in the questionnaire. One hardware manufacturer observed: "We can respond to a specific request concerning those who may require specially designed systems. All one need to do is to contact our organization and we will do everything we can to comply with special requests on product design, where feasible."

Others were less optimistic about meeting special needs. Said one software manufacturer: "Many of these are tough issues. The key problem is not technical but economic. The major markets continue to be for the majority of users who can make do with the old keyboard technology. Keyboards are not great for anyone, but they are pretty good for an overwhelming majority. Multiple, simultaneous keystrokes permit, for those people, a smaller, cheaper and simpler (perceived simpler) input device than a large array of special-purpose keys would. The special needs of any small segment remain very hard to justify due to the 'dis-economics' of small scale. The jury is still out on alternative input methods. Many of us have fooled around with mice, light pens, touch screens and related devices. These things are nice and it is always fun to work with new, non-standard solutions to old problems. But the market does not buy very many things that are not like the old keyboards. 'Protected' programs are irritating for all of us. But (again) so many programmers and small software businesses have lost such high multiples of their income through piracy that protection is probably here to stay."

Tabulations

Hardware

1.	Keyboard separable?	56% Yes	
2.	Shift lock standard?	100% Yes	
3.	Control lock standard?	22% Yes	
4.	Keyguard available?	78% Yes	
5.	Keyguard hold-down?	89% DNA	Keyguard question was probably misunderstood.
6.	Emulator available?	22% Yes	
7.	Game switch inputs?	11% Yes	
8.	Paddle/joystick?	11% Yes	
9.	Mouse input?	33% Yes	
10.	Touch input?	11% Yes	
11.	Tactile feedback?	67% Yes	
12.	Scrolling?	89% Yes	
13.	Characters 3mm?	44% Yes	
14.	Vertical adjustment?	44% Yes	
15.	Horizontal adjustment?	11% Yes	
16.	Active display?	78% Yes	
17.	Visual signals?	33% Yes	
18.	Luminance adjustable?	89% Yes	
19.	RS-232 available?	89% Yes	
20.	Disk drives?	78% Yes	
21.	Phone modem?	89% Yes	
22.	Phone modem standard?	89% Yes	

Hardware, Con't

23. Expansion slots?	67% Yes
24. If yes, how many?	Given: 5,4,6,8,3,3,2
25. CMOS RAM memory?	22% Yes
26. Visible/audible?	56% Yes
27. Audible only?	11% Yes
28. Visible only?	89% DNA
29. Modular?	67% Yes
30. Portable?	78% Yes
31. Weight?	Given: 8-45 pounds
32. Special offerings?	33% Yes
33. Speech input?	67% Yes
34. Light pen input?	55% Yes
35. Speech synthesis?	44% Met; 33% Consider; 22% DNA
36. Audible, not visible?	22% Met; 22% Consider; 44% DNA; 11% Plan
37. Switches reachable?	56% Met; 11% Consider; 33% DNA
38. Display blink Hz?	67% Met; 11% Consider; 22% DNA
39. Two keys?	22% Met; 33% Consider; 33% DNA
40. LCDs?	44% Met; 33% DNA; 11% No Plans
41. Cord length?	22% Met; 33% Consider; 33% DNA; 11% Plan
42. Multi-level, -task?	22% Met; 22% Consider; 33% DNA
43. Non-QWERTY?	11% Met; 44% Consider; 33% DNA

Software

1. Protected? 58% Yes
2. Audible, visual? 27% Yes
3. One-key commands? 77% Yes
4. Multi-tasking? 23% Yes
5. Multi-level? 27% Yes
6. Analog inputs? 50% Yes
7. Light pen? 88.5% No
8. Special features? 31% Yes
9. Visible beep? 73% Met; 15% Consider
10. Speech synthesis? 38.5% Met; 19% Consider
11. Two-key commands? 61.5% Met; 19% Consider; 8% Plan
12. One task at time? 11.5% Met; 27% Consider
13. Multi-level plans? 27% Met; 8% Plan
14. Other input? 35% Met; 27% Consider; 8% Plan

Please respond by 1 December 1983

We're asking you to take ten (10) minutes to answer some questions about your computer products.

The information you provide for us will be compiled with responses from other manufacturers to produce a report. As thanks for your help, we'll send you a copy of the completed report.

Our interest is in how your products may be used by people with "special needs" such as vision limitations, hearing impairments, physical disabilities, and other restrictions.

As you may know, at least 25 million Americans of all ages have disabilities. These people want to participate in the "computer revolution" as do others who are not disabled. But to do this, people with special needs must have "accessible" computers.

Our report will highlight some fairly simple steps you might want to consider in order to open the market more widely for your products. Some of these steps---such as offering a visible counterpart to an audible signal---might be incorporated into future versions of your computers.

This research is supported by a grant from AT&T. We will supply to all manufacturers who cooperate in this study a copy of the report. And we will share our findings as well with people who are disabled.

Thank you for your help. A self-addressed, stamped envelope is enclosed for your convenience in responding. And we welcome any letters and literature you wish to send us.

I look forward to receiving your response soon.

Sincerely yours,

Frank Bowe, Ph.D.
Project Director and
Visiting Professor

Page 1, University of Arkansas Survey

Computer Model: _____

Manufacturer: _____

Address, Phone: _____

_____

KEYBOARD	Yes	No
1. Is keyboard separable (detached)?	___	___
2. Is shift/lock standard?	___	___
3. Is control/lock standard?	___	___
4. Is a keyguard available for this model?	___	___
If yes, does it have a shift/control "hold down" mechanism?	___	___
5. Is a keyboard emulator available?	___	___
6. Are game switch inputs standard?	___	___
If yes, is paddle or joystick available?	___	___
7. Is "mouse" input available?	___	___
8. Is "touch" input available (on screen)?	___	___
9. Does keyboard have tactile feedback?	___	___

DISPLAY		
1. Is scrolling under keyboard control?	___	___
2. Is character height equal to or more than 3 mm?	___	___
3. May screen be adjusted vertically?	___	___
4. May screen be adjusted horizontally?	___	___
5. Is display "active" illuminated and not LCD?	___	___
6. If "audible" signals are given, is the same information displayed on screen?	___	___
7. Is luminance adjustable?	___	___

Page 2: University of Arkansas Survey

Computer Model: _____

Manufacturer: _____

Address, Phone: _____

_____

OUTPUT	YES	NO
1. Is a RS-232 interface available?	___	___
2. Does this computer use disk drives?	___	___
3. Is a phone modem available?	___	___
If yes, is it standard?	___	___
4. Does this computer have expansion slots beyond the two needed for printer and modem?	___	___
If yes, how many slots in total? _____		
5. Does this computer have CMOS RAM memory?	___	___
6. Are warning signals both visible and audible?	___	___
If no, are they audible only?	___	___
visible only?	___	___

OTHER

1. Is the system modular?	___	___
2. Is it portable?	___	___
If yes, give weight in pounds: _____		
3. Do you, as manufacturer, offer any special peripherals or modifications you believe would help people with special needs?	___	___
If yes, please include descriptive literature when you return this questionnaire.		
4. Is speech input possible with appropriate peripherals?	___	___
5. Is light-pen input possible?	___	___

Computer Model: _____

Manufacturer: _____

Address, Phone: _____

RESPONDING TO SPECIAL NEEDS

Some disabled people tell us they have special problems with some computers. They need to buy expensive custom-designed devices, or customized software, or both to use these computers. They're very interested in knowing if manufacturers are aware of their concern and willing to consider incorporating into the hardware itself the features they need. Please tell us about your interest and plans. If you believe you have met the concern with the above-named computer model, circle "M"; if you are open to considering modifying future models to meet the concern, circle "C"; and if you have definite plans to respond to the need, circle "P". Thank you.

1. Some blind and dyslexic people say they must have their computer rewired somewhat in order to use speech synthesizer add-ons. M C P

2. Some deaf people say that some computers give an audible "beep" to signal something without displaying this information on screen. M C P

3. Some physically disabled people say that some computers have important switches (e.g., on/off) located at the back of the machine, where they are unreachable. M C P

4. Some epileptic individuals say displays blink at more than 5 Hz which might trigger a seizure. M C P

5. Some physically disabled people say they can't hit two keys simultaneously (e.g., control and F). M C P

6. Some blind people say LCD displays cannot be read with an Optacon (a device that translates on-screen information to tactile form). M C P

7. Some physically disabled people say the detachable keyboard is connected by a too-short cable (e.g., less than 4 feet). M C P

8. Some physically disabled people express a keen desire for multi-level programming and multi-tasking capabilities. M C P

9. Some physically disabled people express a desire for a non-QWERTY keyboard (e.g., "one-handed typewriter keyboard"). M C P

Computer Model: _____

Manufacturer: _____

Address, Phone: _____

We've provided this space to make it easier for you to add your own comments. As you've seen, people with disabilities have some interests and concerns about personal computers. Perhaps your company already has heard from some such users. Perhaps you considered special needs when you designed your equipment. Or perhaps you have improved products in the planning stages and you'd like to learn more about how you can meet the special needs of people with disabilities.

Please tell us about it.

And please enclose with your response or send separately any printed literature or personal letters you believe might help us better appreciate your products and your plans.

Thank you.

Send copy of finished report to me: Name _____
Title _____
Address _____
_____

THANK YOU FOR YOUR COOPERATION! A SELF-ADDRESSED, STAMPED ENVELOPE IS ENCLOSED FOR YOUR CONVENIENCE.

Please respond by 1 December 1983

We're asking you to take five (5) minutes to answer some questions about your software products.

The information you provide for us will be compiled with responses from other companies to produce a report. You will get a copy of that report, as will all respondents who help us with this survey.

Our interest is in how your products may be used by people with "special needs" such as vision limitations, hearing loss, and physical impairments.

As you may know, at least 25 million Americans are disabled. They, like other citizens, want to participate in the "computer revolution." To do so, however, they need "accessible" software and hardware.

This survey has three brief parts.

First, you're asked to answer some yes/no questions about your product.

Second, you're asked if you "will consider" or "plan" some changes.

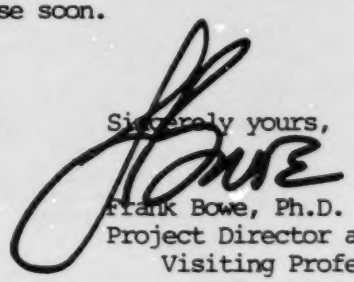
Third, you're asked to tell us anything about your product or plans that you think will help us better appreciate your work.

This research is supported by a grant from AT&T. We will supply to all hardware and software manufacturers cooperating with us a copy of the report. People who are disabled will get copies as well.

Thank you for your help. A self-addressed, stamped envelope is enclosed for your convenience. And we welcome any letters or printed material you wish to send us under separate cover.

I look forward to receiving your response soon.

Sincerely yours,



Frank Bowe, Ph.D.
Project Director and
Visiting Professor

Software Name: _____

Manufacturer: _____

Address, Phone _____

_____

	YES	NO
1. Is the software "protected"?	___	___
2. Does the software show on-screen and indicate auditorially critical information?	___	___
3. Are most commands needed "one key" commands?	___	___
4. Is multi-tasking possible?	___	___
5. Is multi-level programming possible?	___	___
6. Can analog inputs be used (e.g., paddles, joysticks)?	___	___
7. Can a light pen be used as input?	___	___
8. Does the software have any special features incorporated specifically so that problems users with "special needs" encountered during development could be resolved?	___	___

If yes, please tell us about it.

PLEASE TURN THE PAGE

Software Name: _____

Manufacturer: _____

Address, Phone _____

_____

Some people with disabilities tell us they have problems using some software. To the issues below, please indicate if you believe you've met the concern (circle "M"), will consider modifications to meet the concern (circle "C"), or have definite plans to meet the concerns ("P").

1. Some deaf people say that information and directions are given by means of a "beep" or a synthesized-voice command they can't hear. M C P

2. Some blind people say that they cannot send to a speech synthesizer (e.g., Votrax Type-n-Talk) information from a "protected" software program. They say they must spend large sums of money modifying the software and/or hardware in order to be able to use the software. M C P

3. Some physically disabled people say they cannot simultaneously depress two keys, e.g., Control and F1. M C P

4. Some physically disabled people say they cannot use their computers for more than one task at once, something they at times urgently need to do. That is, some use a computer for environmental control, security alarm, and telephone-use purposes. They would like a "multi-tasking" capability that would let them jump back and forth between programs without losing either in memory. M C P

5. Some physically disabled persons express a keen frustration in that products from one set of software cannot be used as input to another. Is "multi-level" programming something you have or may soon have? M C P

6. Some physically disabled people cannot use a keyboard much if at all and prefer to use a light pen, a touch screen, a mouse, and speech input. Do you have plans to make it easier for them to do so? M C P

7. Please add any other comments you may have.

Software Name: _____

Manufacturer: _____

Address, Phone: _____

_____

We've raised some issues in this questionnaire. Perhaps you have comments to make or plans to report; possibly, you know of peripherals or add-ons that can be used with your software to meet special needs. It is possible, particularly with multi-level and multi-task programming, that a "next generation" of hardware and software will be needed before progress can be made as requested by some people with disabilities; e.g., a 32-bit superminicomputer might be the device needed for multi-task programming. Please take advantage of the space below to add any comments you may have.

Please send to me a copy of the report produced by this survey project:

Name _____

Title _____

Address _____

_____

THANK YOU. PLEASE USE THE STAMPED, SELF-ADDRESSED ENVELOPE TO RESPOND. AND WE WELCOME ANY SEPARATELY MAILED LITERATURE YOU WISH TO SEND US.

HARDWARE MANUFACTURERS

Apple Computers, Inc.
20525 Mariani Avenue
Cupertino, CA 95014

Atari, Inc.
P.O. Box 61657
Sunnyvale, CA 94086

Bytec Management Corp.
Hyperion Division
8 Colonnade Rd.
Otawa, Ontario, Canada K2E7M6

Coleco Industries, Inc.
999 Quaker Lane South
West Hartford, CT 06110

Columbia Data Products, Inc.
9150D Rumsey Rd.
Columbia, MD 21045

Commodore Business Machines Inc.
1200 Wilson Drive
West Chester, PA 19280

Compaq Computer Corp.
20333 FM 149
Houston, TX 77070

Digital Equipment Corp
146 Main Street
Maynard, MA 01754

Eagle Computer Inc.
983 University Ave.
Los Gatos, CA 95030

Epson America
Computer Products Division
3415 Kashiwa St.
Torrance, CA 90505

Franklin Computer Corp.
2128 Rte. 38
Cherry Hill, NJ 08002

IBM Corporation
Entry Systems Division
P. O. Box 1328
Boca Raton, FL 33432

Kaypro Corp.
533 Stevens Ave.
Solana Beach, CA 92075

Mattel Electronics Inc.
3600 Sepulveda Blvd.
Manhattan Beach, CA 90266

Micro Technology Unlimited
2806 Hillsborough St.
Raleigh, NC 27605

Morrow, Inc.
600 McCormick St.
San Leandro, CA 94577

NEC Information Systems, Inc.
5 Militia Dr.
Lexington, MA 02173

North Star Computers, Inc.
14440 Catalina St.
San Leandro, CA 94577

Radio Shack/Tandy Corp.
300 One Tandy Center
Fort Worth, TX 76102

TeleVideo Systems, Inc.
1170 Morse Ave.
Sunnyvale, CA 94086

Texas Instruments
P. O. Box 53
Lubbock, TX 79086

Victor Technologies, Inc.
380 El Pueblo Rd.
Scotts Valley, CA 95066

Wang Laboratories, Inc.
1 Industrial Ave.
Lowell, MA 01851

SOFTWARE MANUFACTURERS

Ashton-Tate
10150 W. Jefferson Blvd.
Culver City, CA 90230

Control Data Publishing Co.
P.O. Box 261127
San Diego, CA 92126

FriendlySoft, Inc.
3638 W. Pioneer Pkwy.
Arlington, TX 76013

FYI Inc.
P. O. Box 26481
Austin, TX 78755

Graphic Software, Inc.
1972 Massachusetts Ave.
Cambridge, MA 02140

Harcourt Brace Jovanovich, Inc.
1250 Sixth Avenue
San Diego, CA 92101

Leading Edge Products, Inc.
225 Turnpike St.
Canton, MA 02021

Lifeboat Associates
1651 Third Ave.
New York, NY 10028

Lifetree Software, Inc.
411 Pacific St.
Monterey, CA 93940

Logo Computer Systems, Inc.
9960 Cote de Liesse
Lachine, Quebec, Canada H8T1A1

Lotus Development Corp.
161 First St.
Cambridge, MA 02142

MicroPro International Corp.
33 San Pablo Ave.
San Rafael, CA 94903

Microsoft Corp.
10700 Northup Way
Bellevue, WA 98004

Parker Bros.
50 Dunham Road
Beverly, MA 01951

PCsoftware of San Diego
9120 Grammercy Dr.
San Diego, CA 92123

Peachtree Software Inc.
3845 Peachtree Rd. N.E.
Atlanta, GA 30326

Pearlsoft
25195 Southwest Pkwy.
Wilsonville, OR 97070

Perfect Software, Inc.
702 Harrison St.
Berkeley, CA 94710

Software Technology for Computers, Inc.
153 California Street
Newton, MA 02158

Spinnaker Software Corp.
215 First St.
Cambridge, MA 02142

The Learning Co.
545 Middlefield Rd.
Menlo Park, CA 94025

VisiCorp
2895 Zanker Rd.
San Jose, CA 95134

PFS
422 Aldo
Santa Clara, CA 95050

All programs administered by and services provided by the Arkansas Rehabilitation Research and Training Center are rendered on a nondiscriminatory basis without regard to handicap, color, sex, or national origin in compliance with the Rehabilitation Act of 1973 and Title VI of the Civil Rights Act of 1964. All applicants for program participation and/or services have a right to file complaints and to appeal according to regulations governing this principle.